

THE PLASMA IN THE VICINITY OF VENUS. COMPARISON
OF THE RESULTS RECEIVED BY MEANS OF
VENERA-4 AND MARINER-5

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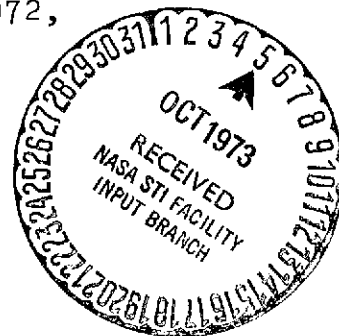
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T. K. Breus and K. I. Gringauz

As is well known, the spacecraft Venera-4 and Mariner-5 /279*
performed experiments to measure the concentration of charged
particles in the nocturnal and diurnal ionosphere of Venus,
as well as to determine the shock wave formed when the solar
wind passes around the planet. It is of interest to compare
the results of these experiments. Figure 1 schematically shows
the preplanetary segments of the trajectories of both spacecraft,
drawn in the orbital plane [1]. A detailed description of the
methods used in the experiments has been already published in
[2, 3, 4, 5]. We shall only give here certain data which are
necessary for the comparison.

The spacecraft Venera-4 measured the concentration of
positive ions in the ionosphere of Venus and the fluxes of
positive ions in the solar wind at the first stage of the pre-
planetary segment of the spacecraft trajectory, using three-
electrode flat and hemispherical traps of charged particles.
Measures were taken to expand the angular directional diagram
of the traps. The range of measured concentrations in the flat
traps was $50 - 5000 \text{ cm}^{-3}$, and in the hemispherical traps —
 $5 \cdot 10^4 - 10^7 \text{ cm}^{-3}$. Measurements with the flat traps were per-
formed once every seven seconds, and with the hemispherical

*Numbers in the margin indicate the pagination in the
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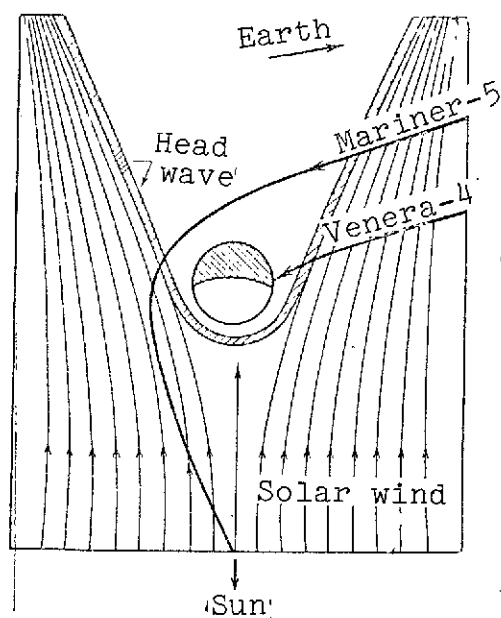


Figure 1. Preplanetary segments of the Venera-4 and Mariner-5 trajectories

traps — each 0.8 seconds. Since, according to the measurement method using flat traps, only one value of two consecutively measured values may be used to determine the ion concentration (n_i), and since the velocity of Venera-4 on the preplanetary segment was 10 km/sec, the data from the flat traps must make it possible to determine the concentration n_i every 150 km of altitude. The spherical traps provide measurements every 8 km. The constant orientation of the spacecraft toward the Sun made it possible to record fluxes

of positive ions from the solar wind in the flat traps.

Mariner-5 measured ions of the solar wind on the preplanetary segment of the trajectory by means of a "Faraday cylinder" — a modulation trap of charged particles.

Observations of the radio eclipse of Mariner-5 by the planet at frequencies of 423.3 MHz and 49.8 MHz made it possible to determine the electron concentration in the ionosphere of Venus.

Let us compare the results of observing the radio eclipse of Mariner-5 by Venus with the results of measuring the ion concentration by means of Venera-4. Venera-4 descended to the night side of the planet close to the morning boundary of the shadow. The hemispherical ion traps did not record any fluxes

throughout the entire preplanetary segment of the flight trajectory for Venera-4. This meant that, when the probe measurements on Venera-4 were developed, the measurement limits of the charged particle traps were selected under the assumption (as follows from data given in the literature; see, for example, [6, 7]) that the ionosphere was much denser than it is in actuality.

Measurements with the hemispherical traps thus made it possible to establish that the ion concentration in the nocturnal ionosphere of Venus does not exceed $5 \cdot 10^4 \text{ cm}^{-3}$ anywhere, which does not contradict the measurement data in the nocturnal ionosphere of the planet obtained by Mariner-5 (see Figure 1).

As has already been noted, measurements of small ion concentrations were performed within an altitudinal interval of 150 km, and made it possible to establish the upper limit of $n_i \sim 10^3 \text{ cm}^{-3}$ at altitudes greater than 300 km. Data from two measurements, which were performed at low altitudes, could not be identified due to radio interference.

Based on observations of the radio eclipse of Mariner-5, the electron concentrations in the nocturnal ionosphere of Venus, at altitudes greater than 300 km, exceed 10^3 cm^{-3} only /280 in a thin layer on the order of 150 km (Figure 2). Consequently, they could not be detected in measurements on Venera-4, since the altitudinal measurement interval by traps of the necessary sensitivity was approximately 150 km.

As may be seen from Figure 2, the results of measuring n_e and n_i in the nocturnal ionosphere, based on data from Venera-4 and Mariner-5, do not contradict each other, and point to the quasineutrality of the nocturnal ionosphere of Venus.

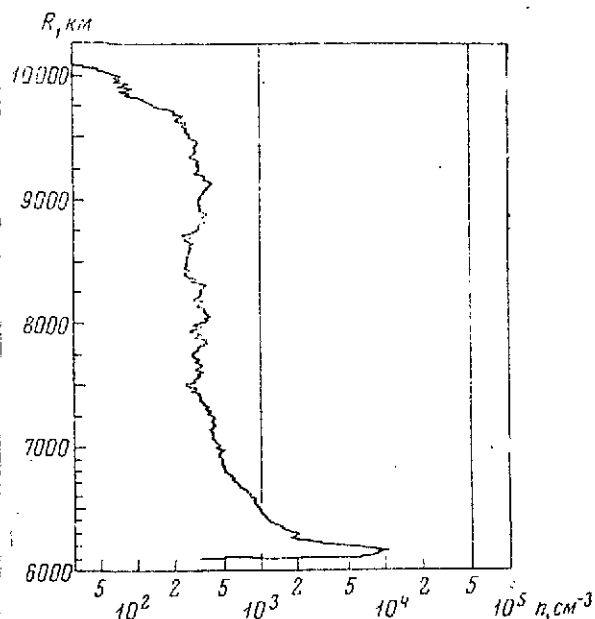


Figure 2. Concentration of charged particles close to Venus based on data from Mariner-5.

The vertical lines show the upper limits for n_1 and n_e based on data from Venera-4.

Let us now compare the results pertaining to the interaction of the planet with the solar wind. As experiments have shown, both the spacecraft intersected the region of perturbation of the solar wind fluxes of the planet; this region has been interpreted as the region of a shock wave. Figures 3 and 4 show the results of plasma measurements, and also measurements of the magnetic field on both spacecraft close to the planet. It is apparent that in both cases there was a synchronous change in the parameters characterizing the plasma and the magnetic field.

Two characteristics, which were apparent when comparing these results, must be pointed out: (1) the differing nature of the change in the fluxes with a change in the distance from the planet surface; (2) the differing increase in the fluxes behind the shock wave front. The first characteristic is related to the difference in the trajectories of the spacecraft (see Figure 1). In contrast to Venera-4, Mariner-5 intersected the front of the shock wave twice: during the flight to the planet, at the point designated as 1 in Figure 4, and when leaving the region of the shock wave at point 5. Points 2 and 4 in Figure 4 designate the intersection of Mariner-5 with the rarefaction zone formed behind the planet.

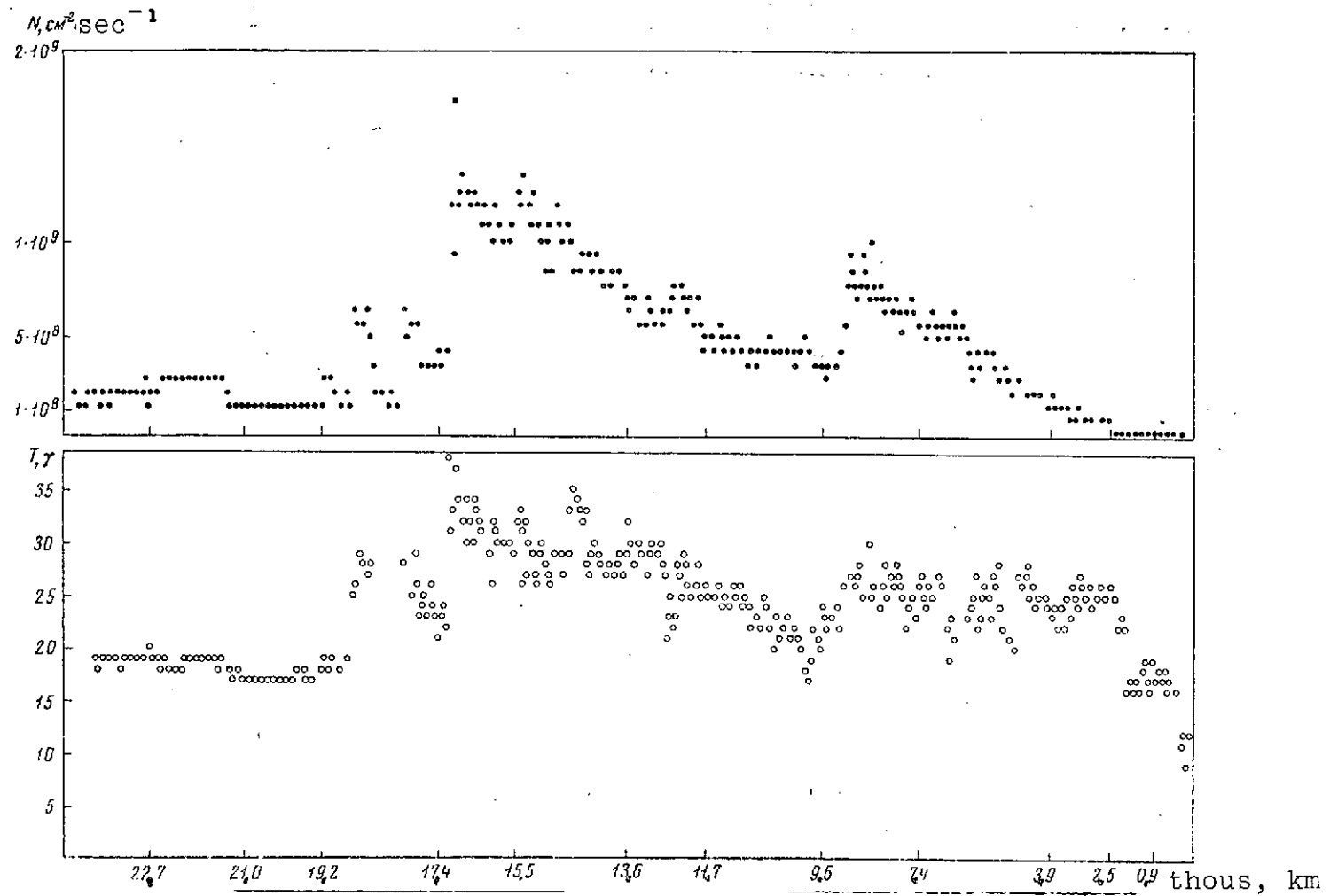


Figure 3. Measurements of the flux of ions N_i and the strength of the magnetic field T close to Venus, based on data from Venera-4.

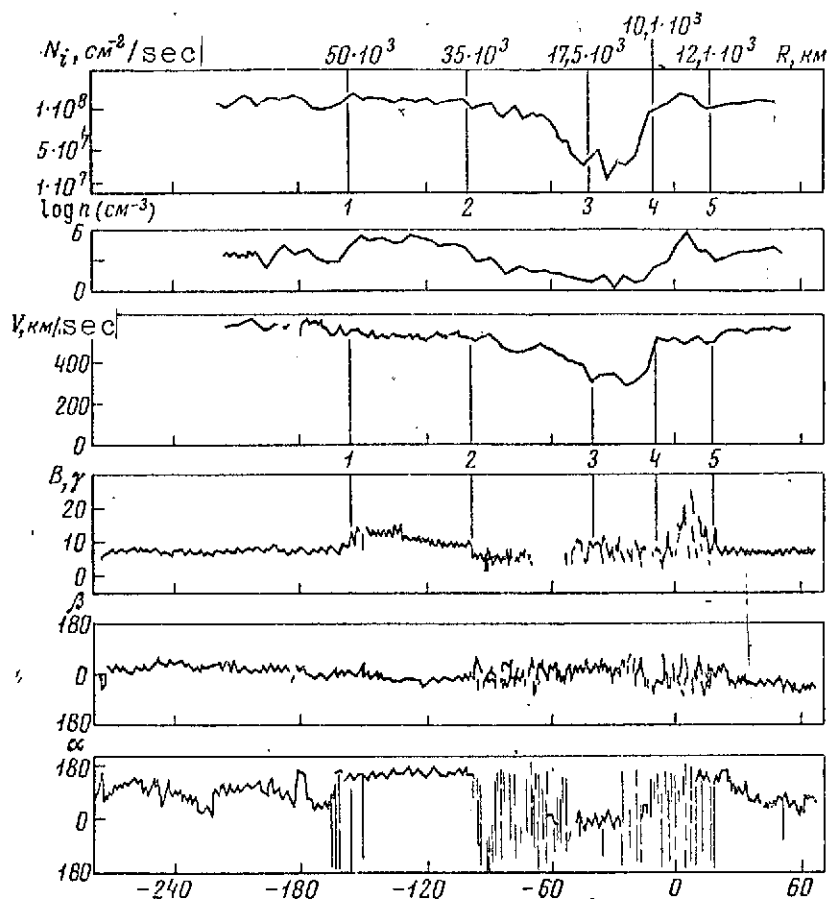


Figure 4. Measurements of the flux of ions N_i , the concentration of charged particles n , the velocity of solar wind particles V , the strength of the magnetic field B , the angles of the magnetic declination β and inclination α .

Let us now examine the second characteristic of the results of plasma measurements. An examination of Figure 3 shows that, at distances $\sim 19,000$ km from the planet surface, Venera-4 observed an increase in N_i on the order of magnitude of the solar wind ion fluxes, which was identified by the authors of the experiment with the shock wave front. As may be seen from Figure 4, when Mariner-5 intersected the shock wave front, the increase in the fluxes was much smaller.

We should first note that the maximum value of N_i , measured on Venera-4, raises no doubts in terms of experiment, whereas the minimum value may be somewhat (by a factor of 2) too low, due to the imprecise allowance for the influence of photocurrents from the trap corrector. Due to this, the increase in N_i behind the shock wave front may be decreased by a factor of ~ 5 . However, this increase is large as compared with that observed on Mariner-5.

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This difference may be explained by the fact that behind the shock wave front the direction of the solar wind particle fluxes changes greatly, and the isotropic nature of their motion increases. The orientation of the trap on Venera-4 was more favorable for receiving the fluxes than was the orientation of the trap on Mariner-5. The latter was always oriented toward the Sun, and the angle between the normal to the trap corrector on Venera-4 and the direction to the Sun, during the preplanetary measurement session, was $\sim 45^\circ$, and was close to the possible direction of particle fluxes behind the front (at least, for a circumterrestrial shock wave the orientation of the solar wind fluxes behind the front is approximately characterized by the angle with respect to the direction towards the Sun). As of the present, we have performed an additional analysis of the possible influence of the changes in the direction of ion fluxes behind the shock wave front upon the trap readings.

Since the orientation of the trap with respect to the direction towards the Sun and the velocity vector of Venera-4 was practically unchanged throughout the entire preplanetary segment, additional fluctuations in the flux of positive ions (which also amounted to an order of magnitude, see Figure 3) may be attributed to large and actual changes in the magnitude

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of the fluxes behind the shock wave front. Another possibility is the influence of changes in time of the characteristics of the solar wind in the unperturbed interplanetary space. This possibility may be verified by comparing these data with the results of simultaneous measurements of the solar wind in interplanetary space performed on Mariner-5. This comparison is given in [8].

It must be kept in mind that Venera-4 intersected the shock wave at different distances from the planet than Mariner-5 (see Figure 1), which may have caused the differences in the phenomena observed. Thus, it is apparent that the "rarefaction zone" observed on Mariner-5 could have been observed on Venera-4 at different distances from the planet. It is possible that very small values of N_1 and the magnetic field at the very end of the graphs in Figure 3 correspond to the rarefaction zone.

Further analysis and comparison of the data obtained on Venera-4 and Mariner 5 will make it possible to clarify some of the results, which are still not completely clear. Some of them will probably only be clarified after future experiments.

However, it is apparent that plasma measurements on Venera-4 and Mariner-5 established one and the same physical phenomena which supplement each other and which it is interesting and advantageous to compare.

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